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VERIFICATION OF NUMERICALLY CONTROLLED MACHINE PROGRAMS BY THE --ETC(U)
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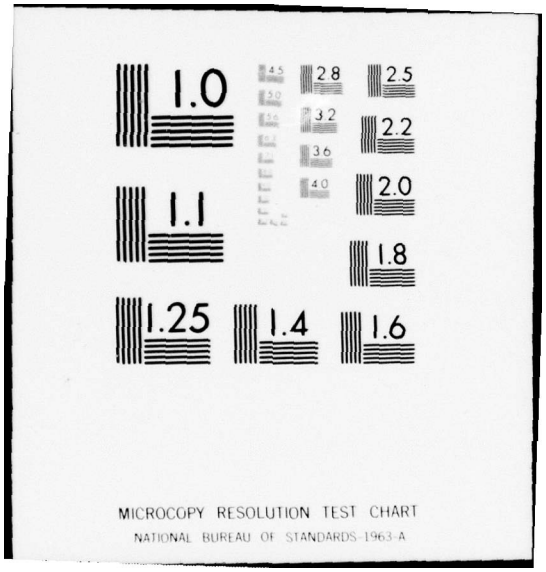
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WVT-TR-77011

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VERIFICATION OF NUMERICALLY CONTROLLED MACHINE PROGRAMS BY THE AUTOMATIC DRAFTING MACHINE

D. CONCORDIA

March 1977

BENET WEAPONS LABORATORY
WATERVLIET ARSENAL
WATERVLIET, N.Y. 12189

TECHNICAL REPORT

AMCMS No. 3297.06.7484

PRON No. M1-4-A1559(01) M7-M7

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1. REPORT NUMBER: WVT-TR-77011 ✓	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): VERIFICATION OF NUMERICALLY CONTROLLED MACHINE PROGRAMS BY THE AUTOMATIC DRAFTING MACHINE.	5. TYPE OF REPORT & PERIOD COVERED: Technical rept.
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): D. Concordia	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Benet Weapons Laboratory ✓ Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 3297.06.7484 PRON No.M1-4-A1559(01)M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Armament Research and Development Command Dover, New Jersey 07801	12. REPORT DATE: March 1977
	13. NUMBER OF PAGES: 48
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 54p.	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Numerical Control Automatic Drafting Machine

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a report on the modifications made to the Gerber automatic drafting program to allow for the verification of numerical controlled machine programs on the automatic drafting machine. Programming changes were made so that the eleven most-used machines at Watervliet Arsenal can be verified.

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ILLUSTRATION

INTRODUCTION

Watervliet Arsenal has a large variety of makes of numerically controlled (N.C.) machines. For about the past three years a Gerber automatic drafting machine (ADM), with a Honeywell 316 mini-computer control, has been used to verify the N/C tapes. Unfortunately, no universal language exists for the programming of all N.C. machines and in fact almost all manufacturers differ in the programming for their machines. The Gerber (ADM) method of programming obviously could not allow the verification of all types of N.C. machines.

In the fall of 1975, a meeting of ADM and NC programming personnel was held and it was concluded that an attempt would be made at modifying the existing Gerber drafting program so that different NC machines could be verified. A priority list of eleven makes of machine based on usage, was compiled which included the following:

1. Bostomatic - vertical spindle mill
2. LeBlond - CXR - horizontal lathe (small components)
3. LeBlond - horizontal lathe (tubes)
4. Pratt & Whitney Wolverine - vertical spindle mill
5. Lodge & Shipley - Lathe
6. Cincinnati Hydrotel - vertical spindle mill
7. Bullard VTL - vertical lathe
8. CIM-X 720 - horizontal spindle mill and drill
9. CIM-X A6 - horizontal spindle mill and drill
10. XLO Chucker - vertical lathe
11. Cincinnati Turning Center - horizontal lathe

Changes to the existing program were completed by 1 January 1976 enabling the verification of the eleven machines. A description follows, of the changes made for 9 of the 11 machines since the Pratt & Whitney Wolverine and the Lodge and Shipley tapes could already be verified

with the Gerber drafting program without changes. All changes made appear in appendices A-H, written in the Honeywell assembly language, with comments in the right hand column.

It should be pointed out that parameters used for each machine were also incorporated in the program for each particular machine. In this way, when the program for a particular machine is loaded, the correct parameters are included. Parameters differing from one machine to another include the format statement for the coordinate values and the axis select, which allow selecting X, Y or Z for the horizontal and vertical axis.

BOSTOMATIC

Incremental

The Bostomatic machine may operate in either the absolute or incremental modes (i.e., with coordinate values either referenced to a fixed zero position or referenced to the present position of the pen). The changes required for the incremental mode were minor. They included the following:

1. Read a G1, G2, G3 command as a G01, G02, G03.

2. Read only Code G01, G02, G03, G40, G41, G42 and ignore any other G code. Read a G40, G41, G42 as a G01.

The G command instructs the machine to move either linearly (G01) or in a circular motion (G02 clockwise, G03 counter-clockwise). As the Gerber program existed a G1 would be read as a G10, which is the code to draw linearly, but at a scale ten times.

The change involved only one instruction, which was eliminated from the program since this instruction made the assumption that zero was the second digit of any G code by shifting the contents of the memory location holding the G code number left 4 positions. This memory location stores the number, in base two, so shifting left would fill the 4 right most memory bits with zeros.

The interpreting of a G code by the Gerber program is done in the following manner. At a particular point in the program, the A register (the working register of the computer) contains the G number in coded form. For example, if a 60 were the G code, the number in the A register would be an octal 140 or in binary, a 01 100 000. The first four bits, starting from the right, contain the right most digit of the G code, in this case, a zero. Since this number could be as great as a nine in decimal, which would be 1001 in binary, four bits are required to store the right most number of the G code. The next four bits, 5 through 8, contain the left hand number of the G code, in this example, a six. The G code is now compared to the coded form of a G number already stored in a certain location in memory. If the numbers are equal, the program jumps to the appropriate place in the programs which executes the command based on the particular G code used. In the example used here, a G60, which is the code to move linearly at a scale of 100, the program would go to that place in the program which executes the command at a scale 100 times the values given. If the G code should be greater or less than the number to

which it is being compared, the program could take either of two paths. It would either compare the G code to the next lower coded number in memory or would interpret the code based on the fact that it is greater than one number but less than another. As far as changes made so that G codes for the Bostomatic Incremental tape would be read correctly, the appropriate comparisons were made, replacing the ones which already existed. For example, to read a G42 as a G01, the A register, which would contain the coded form of a 42 (1000010), would be compared to a memory location which contains a coded 42. They would be equal so the program would jump to the place in the program which makes a linear move since it was desired to read a G42 as a G01. Changes made to allow for the running of a Bostomatic Incremental tape appear in Appendix A.

BOSTOMATIC

Absolute

The changes made to the Gerber program to accommodate the running of a Bostomatic absolute N.C. tape included the following:

1. Read only a G01, G02, G03, G40, G41, G42 and ignore any other command. Read a G40, G41, G42 as a G01.

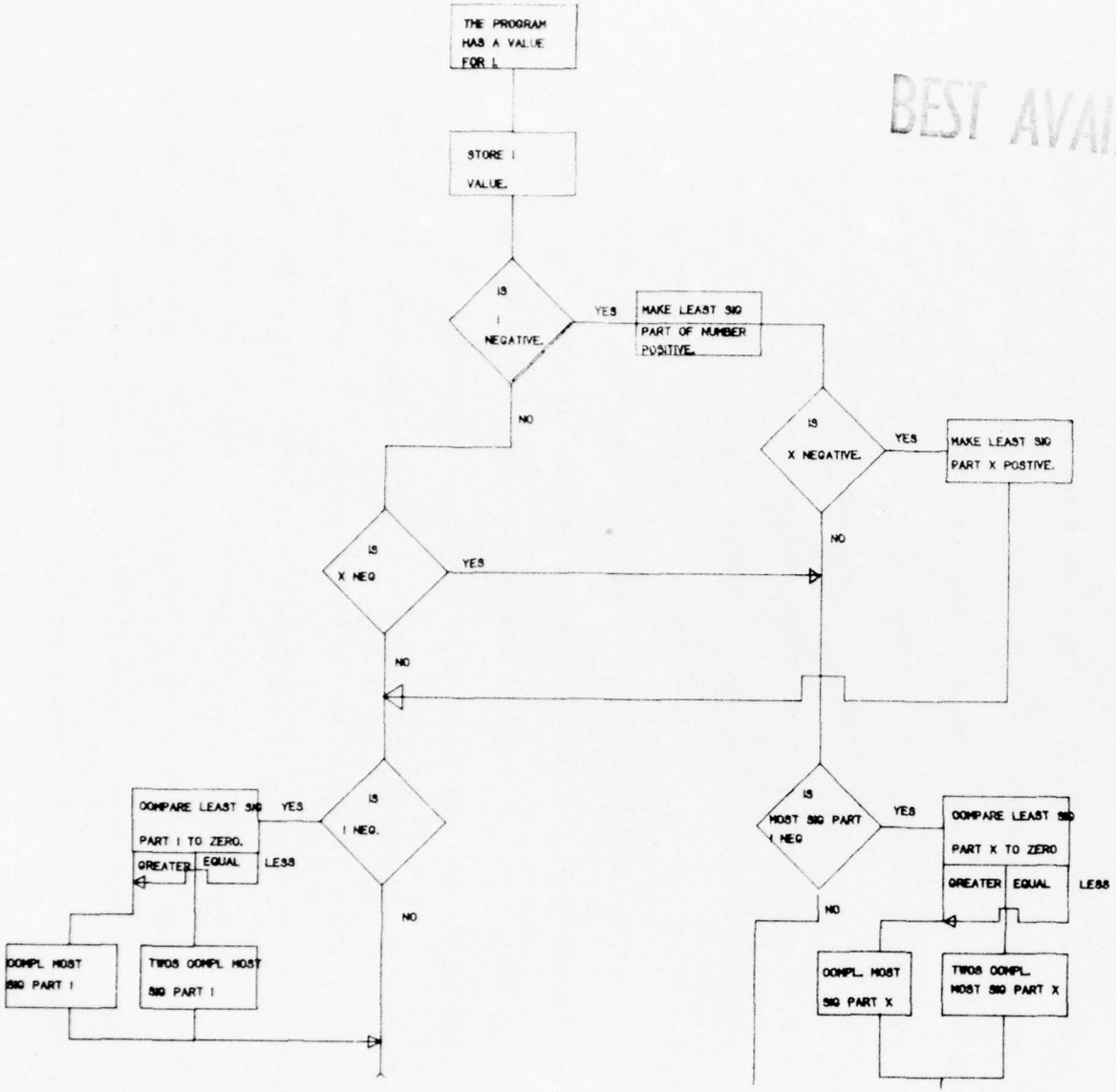
2. Read a G1, G2, G3 as a G01, G02, G03.

3. Read the I, J number of a circular command in the appropriate way.

The changes for Items 1 and 2 are the same as for the Bostomatic Incremental and are explained under that section. The changes needed for the correct reading of a circular command on a Bostomatic absolute tape, Item 3, will now be given.

A circular command requires four different numbers X, Y, I, and J values. For the Gerber program, the X and Y values are the coordinates of the end point of the arc being drawn. The I and J are horizontal and vertical distances respectively from the arc center to the starting point of the arc. The Bostomatic X and Y values are the same as the Gerber but the I and J are the coordinates of the center of the arc relative to zero position. The changes needed to accommodate this difference became rather involved. A flow chart (Fig. 1) is included to help explain the programming. The chart shows the program for calculating a new I value. The programming for calculating a new J is the same except all X and I are replaced by Y and J. The basic approach of the programming was to subtract the Bostomatic I (or J) value from the previous X (or Y) value to obtain the incremental distance from the center of the arc to the starting point, which is the value needed for I (or J) in the Gerber program (in some cases, such as when the I value is negative and the previous X value positive, the two values would be added to obtain the new I value).

In order to explain the programming changes, the manner of storing a decimal number in memory should be explained. The Gerber system allows for a number with up to three places to the left of the decimal point and five to the right. The number is stored in two memory locations with each location having 15 bit positions, plus a bit position for the sign. A zero is stored with all bit positions containing zero. The number .00001 would contain the binary number 000 000 000 000 001,



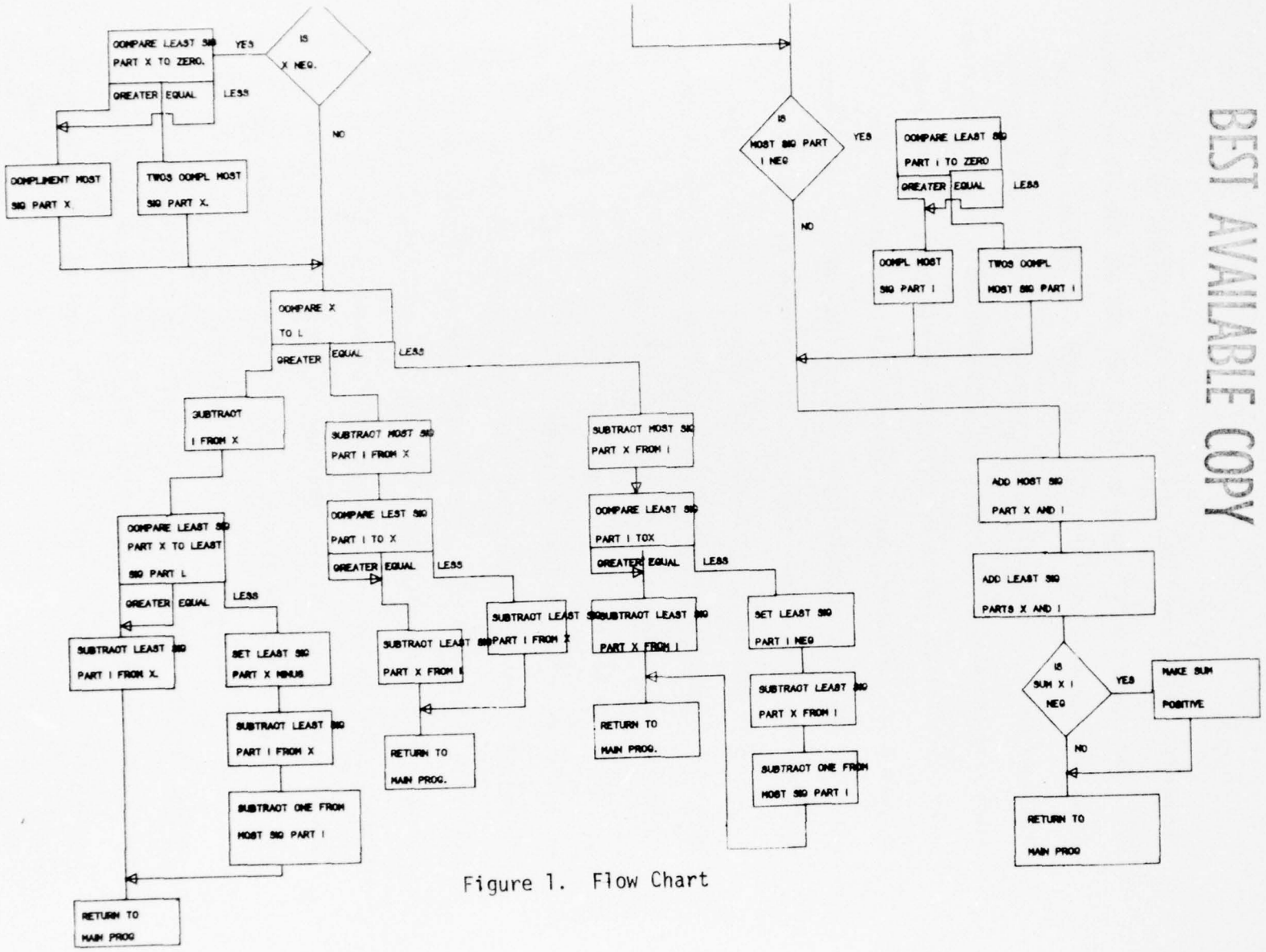


Figure 1. Flow Chart

the number .00002 would be stored as the binary number 000 000 000 000 010. The number .00003 would appear as 000 000 000 000 011 or in other words, the binary number 3 (11). This method of storing the number continues until the memory location contains 111 111 111 111 111 at which time increasing the number by .00001 would store a 1 in the other memory location and return this location to all zeros. As the number increased still further, this location would again increase until it contained all ones, at which time a further increase of .00001 would again add one to the other memory location, making it a 10 and return the location containing all ones to all zeros. A negative number is stored as the complement of the most significant part of the number and the two's complement of the least significant part.

Referring now to Figure 1, when an I value is found, this value is stored and tests are made to see if X and I are negative. If they are negative, they are set positive by complementing the number since it is desired to work with only positive numbers. If the I and X values have opposite signs they are added to obtain the incremental distance from the center of the arc to the starting point. With the same sign for X and I values, the smaller number is subtracted from the larger to obtain the incremental distance desired. When the adding or subtracting is done, the program then returns to the main program with the newly calculated form of I (or J) in a particular memory location. The Gerber program can now operate on the circular command with the I (or J) value in the form required (see Appendix B).

The subtraction process used in the programming requires some explanation. The most significant part of the smaller number is first subtracted from the most significant part of the larger number. The least significant parts of the two numbers are then compared. If the most significant parts had been equal, the smaller of the least significant parts of the two numbers is subtracted from the larger. Otherwise, if the least significant part of the one number is less than the least significant part of the other number, but its most significant part is less, the sign bit of the smaller least significant part number is set to one. A one is then subtracted from the most significant part of the number and the two least significant parts are then subtracted.

To make a negative number (a number with a sign bit in its most significant part of one) positive, the two complement of the least significant part is taken and the complement of the most significant part. The one exception is if the least significant part of the number is zero, in which case, the two complement of the most significant part is taken.

LeBlond and LeBlond CXR

Both LeBlond machines required similar changes to facilitate the verification of the tapes. The changes included the following:

Treat G92, G33, G34, G35, as a G01; ignore other G commands except G01, G02, G03.

The programming needed for these changes was similar to the G code changes made for the Bostomatic Incremental, which are described

under that section. One additional programming change was required because of a peculiarity which occurred with the G04 command. This command occurs in the LeBlond tape but for verification purposes, it was desired to ignore it. The G04 code is a modal command, meaning if G04 is given, any statement following, without a G code, is assumed G04. By ignoring G04, no G number is stored in memory so, when modality occurs with the G04, the program finds no G number for the statement and assumes an error, which is not the desired result. To correct this, a 4 was put into the G number memory location each time a G04 occurred (see Appendix C).

Cincinnati Hydrotel

The Cincinati Hydrotel required the following programming changes:

1. Circular command I, J, values defined same as for Bostomatic Absolute.

2. Two statements required to define an arc.

The first change was the same as for the Bostomatic Absolute and is given under that section. The defining of an arc with two statements is done in the following manner. The first statement has a G02 or G03 code, with an X and Y, followed by a value. These values are the I and J values (the distance from coordinate zero to the center of the arc) for the arc being programmed. The X and Y, which are used here, could be replaced by an I and J. The next statement would not have a G code, only an X and Y, followed by a value. These values

are the coordinate of the end point of the arc being programmed.

The approach used to accomplish these changes was done in the following manner. When a G02 or G03 was encountered, a one was stored in a particular memory location. Otherwise, a zero is stored at this location. When an X or Y is encountered, this location is checked and if it is one, the X or Y is changed to an I or J. In this way, the program thinks it has an I or J value and this value is then stored in memory. Upon encountering the next statement, it is assumed circular and the X and Y values, along with the I and J values stored from the previous statement, are used in executing the circular command (see Appendix D).

BULLARD VTL

The change needed for the Bullard VTL was minor requiring only that a G03 command be a clockwise circular command and a G02, a counter-clockwise circular command. The Gerber program interpreted a G03 as counter-clockwise and a G02 as clockwise (see Appendix E).

CIM-X-720

The CIM-X-720 required changes identical to the Bostomatic Absolute except for a difference in interpreting I and J values. The CIM-X-720 I and J values are modal, meaning if an I or J is omitted from a statement, its value is assumed the same as the value for I or J in the previous statement. The Bostomatic differed in

that if an I or J value is omitted, it assumes an X or Y value of the previous statement for the value of I or J.

The approach used in the programming was to simply store I and J values each time they were found and then reload in the proper location whenever a new statement is encountered. In this way, If a statement is a circular command and an I or J is omitted, the previous I or J will already be in the proper memory location (see Appendix F).

CIM-X-A6

The CIM-X-A6 changes were the same as the ones made for the Bostomatic Absolute and CIM-X-720 except for the way a G93 code is interpreted. The G93 has a B value which is used as an X value except it is multiplied by a factor of 29.5719. To program for this change, if a G93 code is encountered, it has the B changed to an X. The scale factor for the machine for the X axis is then changed to 29.5719. The command is then executed and the scale factor is changed back to one. At the same time, a one is stored in a particular memory location. In this way, if the following statement after a G93 has a G code this particular memory location is checked and if it is a one, the scale factor for the X axis is again changed to 29.5719 (see Appendix G).

XLO Chuckers

The XLO Chucker change was the same as for the Bullard VTL and is explained under that section (see Appendix E).

Cincinnati Turning Center

The Cincinnati Turning Center programming uses a plus or minus sign before I or J values whereas the Gerber program does not use a sign before I or J values. If a minus sign is used the program will output an error. To correct this at the point in the program where an I or J value is encountered, a check is made to see if the next character is a minus. If it is minus, it is replaced by a plus sign which will allow the correct reading of the program in the Gerber format (see Appendix H).

CONCLUSION

The verifying of numerical control tapes by the automatic drafting machine has proven a feasible means of finding errors in programs. With the ability to verify the eleven most used machines at Watervliet Arsenal, the process has become much more useful. The modification of the Gerber drafting program has shown that the capability exists to change the program to accommodate any make of N.C. machine. The modifications necessary to verify the remaining N.C. machine can thus be made as the need arises.

APPENDIX A

BOSTOMATIC (INCREMENTAL)

LOCATION	INSTRUCTION	COMMENT
2205	NOP	Read G1 etc. as G01 etc.

To read only G01, G02, G03, G40, G41, G42 and ignore any other G command.

2212	CAS = '102	Compare 42
2213	JMP* '505	
2214	JMP 2261	
2215	CAS = '100	Compare 40
2216	JMP 2261	
2217	JMP 2261	
2220	JMP 2253	
2230	DAC '102	
2231	DAC '100	

APPENDIX B

BOSTOMATIC ABSOLUTE (For I)

LOCATION	INSTRUCTION	COMMENT
15205	JST* 15675	
15211	JST* 15676	
15232	JST* 15676	
15335	JST* 15675	
15675	12026	
15676	12041	
12026	000000	
12027	LDA* 12054	
12030	CAS 133	Changes take the two's complement of the most significant part of I, X values, if it is negative and if its least significant part is 0.
12031	JMP' 12033	
12032	JMP 12036	
12033	LDA* 12055	
12034	CMA	
12035	JMP* 12026	
12036	LDA* 12055	
12037	TCA	
12040	JMP* 12026	
12041	000000	
12042	IAB	
12043	CAS 133	
12044	JMP 12046	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION		COMMENT
12045	JMP	12051	
12046	IAB		
12047	CMA		
12050	JMP*	12041	
12051	IAB		
12052	TCA		
12053	JMP*	12041	
12054	15451		
12055	15450		

Changes to Bostomatic Absolute program so G41, 42 will make pen down, G40 pen up.

2214	JMP	2232	If G42
2216	JMP	2232	If G41
2217	JMP	2235	If G40
2232	LDA	1 (160)	Load 232 (pen position) with 1.
2233	STA	232	
2234	JMP	2261	
2235	LDA	2 (225)	Load 232 (pen position) with 2.
2236	STA	232	
2237	JMP	2261	
2205	NOP	10100	Read G1 etc. as G01 etc.
774	DAC	2650	
2511	DAC	15400	
2120	JMP*	2511	
15400	STA	15452	Store A

APPENDIX B (cont'd)

LOCATION	INSTRUCTION		COMMENT
15401	LDA	323	Store previous Y in 775 most sig.
15402	STA	775	773 least sig.
15403	LDA	324	
15404	STA	773	
15405	LDA	321	Store previous X in 450 most sig.
15406	STA	15450	451 least sig.
15407	LDA	322	
15410	STA	15451	
15411	JMP	15433	
15433	LDA	15452	Reload A
15434	NOP		
15435	JMP*	774	Jump back
777	DAC	15150	
2516	JST*	777	
15150	PZE		
15151	JMP	15360	
15152	IAB		Make least sig. part I pos. if it was neg.
15153	TCA		
15154	SSP		
15155	IAB		
15156	STA	15320	
15157	LDA	15450	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15160	SMI	Check if X is neg.
15161	JMP 15204	
15162	LDA 451	
15163	TCA	Make least sig. part of X positive.
15164	SSP	
15165	STA 15451	
15166	LDA 15320	
15167	JMP 15230	
15170	STA 15320	
15171	LDA 15450	
15172	SPL	
15173	JMP 15176	
15174	LDA 15320	
15175	JMP 15230	
15176	STA 15321	
15177	LDA 15451	
15200	TCA	
15201	SSP	
15202	STA 15451	
15203	LDA 15450	
15204	SPL	Check most sig. part of X, I
15205	CMA	
15206	STA 15450	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15207	LDA 15320	
15210	SPL	
15211	CMA	
15212	ADD 15450	
15213	STA	
15214	IAB	If X and I have opposite signs add them subtract them.
15215	ADD 15451	
15216	SMI	
15217	JMP 15226	
15220	SSP	
15221	STA CAPI+1	
15222	LDA CAPI	
15223	ADD = 1	
15224	STA CAPI	
15225	JMP* 15150	
15226	STA CAPI+1	
15227	JMP* 15150	
15230	SMI	
15231	JMP 15233	If X and I are both positive or negative sign.
15232	CMA	
15233	STA 15320	
15234	LDA 15450	
15235	SMI	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15236	JMP 15240	
15237	JMP 15335	
15240	CAS 15320	
15241	JMP 15550	
15242	JMP 15514	
15243	LDA 15320	
15244	SUB 15450	
15245	STA CAPI	
15246	IAB	Subtract them
15247	CAS 15451	
15250	JMP 15303	
15251	JMP 15303	
15252	SSM	
15253	SUB 15451	
15254	STA CAPI+1	
15255	LDA CAPI	
15256	SUB =1	
15257	JMP 15330	
15261	SUB 15320	
15262	STA CAPI	
15263	IAB	
15264	STA 15501	
15265	LDA 15451	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15266	CAS 15501	
15267	JMP 15300	
15270	JMP 15300	
15271	SSM	
15272	SUB 15501	
15273	STA CAPI+1	
15274	LDA CAPI	
15275	SUB =1	
15276	STA CAPI	
15277	JMP* 15150	
15300	SUB 15501	
15301	STA CAPI+1	
15302	JMP* 15150	
15303	SUB 15451	
15304	STA CAPI+1	
15305	JMP* 15150	_____
15360	STA 15470	
15361	IAB	Store I value
15362	STA 15471	_____
15363	IAB	
15364	SMI	Check if I is neg. if it is, make least sig. part of number positive, up to 204
15365	JMP 15170	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15366	JMP 15152	
15335	CMA	
15336	STA 15450	
15337	JMP 15240	These statements placed here because contents would not stay in location 15260
15330	STA CAPI	
15331	JMP* 15150	
15514	SUB 15320	
15515	STA CAPI	
15516	IAB	
15517	CAS 15451	
15520	JMP* +1	
15521	JMP 15527	
15522	STA 15501	
15523	LDA 15451	
15524	SUB 15501	
15525	STA CAPI+1	
15526	JMP* 15150	
15527	SUB 15451	
15530	STA CAPI+1	
15531	JMP* 15150	
15550	SUB 15320	
15551	STA CAPI	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15552	IAB	
15553	STA 15501	
15554	LDA 15451	
15555	CAS 15501	
15556	JMP 15300	
15557	JMP 13300	
15560	SSM	
15561	SUB 15501	
15562	JMP 15273	

APPENDIX B

BOSTOMATIC ABSOLUTE (For J)

LOCATION	INSTRUCTION	COMMENT
15035	JST* 15673	
15041	JST* 15674	
15062	JST* 15674	
15340	JST* 15673	
15673	12000	
15674	12013	
12000	000000	
12001	LDA 773	
12002	CAS 133	
12003	JMP 12005	Changes take the two's complement of the most significant part of J, Y values, if it is negative and if its least significant part is 0.
12004	JMP 12010	
12005	LDA 775	
12006	CMA	
12007	JMP* 12000	
12010	LDA 775	
12011	TCA	
12012	JMP* 12000	
12013	000000	
12014	IAB	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
12015	CAS 133	
12016	JMP 12020	
12017	JMP 12023	
12020	IAB	
12021	CMA	
12022	JMP* 12013	
12023	IAB	
12024	TCA	
12025	JMP* 12013	
776	DAC	
2512	JST* 776	
15000	PZE	
15001	JMP 15370	
15002	IAB	
15003	TCA	Make least sig. part Y and J positive if they were negative.
15004	SSP	
15005	IAB	
15006	STA 15320	
15007	LDA 775	
15010	SMI	
15011	JMP 15034	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15012	LDA 773	
15013	TCA	
15014	SSP	
15015	STA 773	
15016	LDA 15320	
15017	JMP 15060	
15020	STA 15320	
15021	LDA 775	
15022	SPL	
15023	JMP 15026	
15024	LDA 15320	
15025	JMP 15060	
15026	STA 15321	
15027	LDA 773	
15030	TCA	
15031	SSP	
15032	STA 773	
15033	LDA 15321	
15034	SPL	
15035	CMA	Add Y and J if both are positive or both negative.
15036	STA 775	
15037	LDA 15320	

LOCATION	INSTRUCTION	COMMENT
15040	SPL	
15041	CMA	
15042	ADD 775	
15043	STA CAPJ	
15044	IAB	
15045	ADD 773	
15046	SMI	
15047	JMP 15056	
15050	SSP	
15051	STA CAPJ+1	
15052	LDA CAPJ	
15053	ADD =1	
15054	STA CAPJ	
15055	JMP* 15000	
15056	STA CAPJ+1	
15057	JMP* 15000	
15060	SMI	
15061	JMP 15063	Subtract smallest from largest if J and Y have opposite values.
15062	CMA	
15063	STA 15320	
15064	LDA 775	
15065	SMI	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15066	JMP 15070	
15067	JMP 15340	
15070	CAS 15320	
15071	JMP 15111	
15072	JMP 15532	
15073	LDA 15320	
15074	SUB 775	
15075	STA CAPJ	
15076	IAB	
15077	CAS 773	
15100	JMP 15133	
15101	JMP 15133	
15102	SSM	
15103	SUB 773	
15104	STA CAPJ+1	
15105	LDA CAPJ	
15106	SUB =1	
15107	STA CAPJ	
15110	JMP* 15000	
15111	SUB 15320	
15112	STA CAPJ	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15113	IAB	
15114	STA 15501	
15115	LDA 773	
15116	CAS 15501	
15117	JMP 15130	
15120	JMP 15130	
15121	SSM	
15122	SUB 15501	
15123	STA CAPJ+1	
15124	LDA CAPJ	
15125	SUB =1	
15126	STA CAPJ	
15127	JMP* 15000	
15130	SUB 15501	
15131	STA CAPJ+1	
15132	JMP* 15000	
15133	SUB 773	
15134	STA CAPJ+1	
15135	JMP* 15000	
15340	CMA	
15341	STA 775	

APPENDIX B (cont'd)

LOCATION	INSTRUCTION	COMMENT
15342	JMP 15070	
15370	STA 15472	
15371	IAB	
15372	STA 15473	
15373	IAB	
15374	SMI	
15375	JMP 15020	
15376	JMP 15002	
2510	JMP 2512	
2517	NOP	
2520	NOP	
15532	SUB 15320	
15533	STA CAPJ	
15534	IAB	
15535	cas 773	
15536	JMP* +1	
15537	JMP 15545	
15540	STA 15501	
15541	LDA 773	
15542	SUB 15501	
15543	STA CAPJ+1	

LOCATION	INSTRUCTION	COMMENT
15544	JMP* 15000	
15545	SUB 773	
15546	JMP* 15000	
15547	JMP* 15000	
To read only G01, G02, G03, G40, G41, G42		
2212	CAS ='102	Compare 42
2213	JMP* '505	
2214	JMP 2261	
2215	CAS ='100	Compare 40
2216	JMP 2261	
2217	JMP 2261	
2220	JMP 2253	
2230	DAC '102	
2231	DAC '100	
2254	JMP* '505	

APPENDIX C

LEBLOND

LOCATION	INSTRUCTION		COMMENT
2777	222		G92 treat G01, greater G92 ignore G33, 34, 35 treat G01 G25, 26 ignore
2213	JMP*	505	
2214	JMP	2261	
2232	JMP	2261	
2241	JMP	1075	
2255	JMP	2313	If G04 load 2332 with a 4.
2313	LDA	2331	
2314	STA	2332	
2315	JMP*	505	
2722	JMP	2316	
2316	LDA	2332	If ERNG error about to be printed check in G04 mode, if yes, do not print ERNG.
2317	CAS	2331	
2320	JMP	2741	
2321	JMP*	505	
2322	JMP	2741	
2331	DAC	4	
2104	JMP	2323	
2323	CRA		If G code other than G04, make 2332 zero so ERNG will print.
2324	STA	2332	
2325	JMP	2170	

APPENDIX D

CINCINNATI HYDROTEL

(Changes to Bostomatic Absolute Drafting Program)

LOCATION	INSTRUCTION	COMMENT
2242	15600	
2277	JMP* 2242	
15600	STA 15605	
15601	LDA 160	If G02, G03 store a 1.
15602	STA 15606	
15603	LDA 15605	
15604	JMP* 15607	
15605	Temp storage for A	
15606	000000	
15607	2351	
2212	JMP 2253	
2254	JMP* 505	
2244	15610	Axis date
2070	JMP* 2244	Check if G02, G03 if yes go 15620, if no go 15647.
15610	STA 15605	
15611	LDA 15606	
15612	CAS 160	
15613	JMP 15615	
15614	JMP 15620	
15615	JMP 15647	

APPENDIX D (cont'd)

LOCATION	INSTRUCTION	COMMENT
15620	LDA 15605	
15621	CAS 167	Compare with X
16522	JMP 15624	No
15623	JMP 15627	Yes
15624	LDA 221	Make it a J
15625	JMP* 15626	
15626	2500	
15627	LDA 271	Make it an I
15630	JMP* 15626	_____
2245	15631	
2261	JMP* 2245	_____
15631	STA 15605	
15632	LDA 133	If G01, store 0
15633	STA 15606	
15634	LDA 15605	
15635	JMP 703	_____
15435	JMP 15636	_____
15636	LDA 304	Store previous I, J.
15637	STA 15570	
15640	LDA 305	

APPENDIX D (cont'd)

LOCATION	INSTRUCTION	COMMENT
15641	STA 15571	
15642	LDA 306	
15643	STA 15572	
15644	LDA 307	
15645	STA 15573	
15646	JMP 15663	
15647	NOP	
15650	LDA 15570	
15651	STA 304	
15652	LDA 15571	Load previous I, J.
15653	STA 305	
15654	LDA 15572	
15655	STA 306	
15656	LDA 15573	
15657	STA 307	
15660	LDA 15605	
15661	JMP* 15662	
15662	2430	
15663	LDA 15606	
15664	CAS 160	
15665	JMP 15667	
15666	JMP 15670	

APPENDIX D (cont'd)

LOCATION	INSTRUCTION	COMMENT
15667	JMP* 774	
15670	LDA 133	
15671	STA 15606	
15672	JMP* 505	

APPENDIX E

BULLARD VTL

LOCATION	INSTRUCTION	COMMENT
2257	JMP 2275	
2260	JMP 2276	

APPENDIX F

CIM-X-720
(Changes to Bostomatic Absolute Program)

LOCATION	INSTRUCTION	COMMENT
To make I, J, modal		
15435	JMP 15600	
15600	LDA 304	
15601	STA 15570	
15602	LDA 305	
15603	STA 15571	
15604	LDA 306	
15605	STA 15572	
15606	LDA 307	
15607	STA 15573	
15610	JMP* 774	
2331	15611	
2070	JMP* 2331	
15611	STA 15670	
15612	LDA 15570	
15613	STA 304	
15614	LDA 15571	
15615	STA 305	
15616	LDA 15572	

APPENDIX F (cont'd)

LOCATION	INSTRUCTION	COMMENT
15617	STA 306	
15620	LDA 15573	
15621	STA 307	
15622	LDA 15670	
15623	JMP* 15624	
15624	2430	
2230	'160	
2213	JMP 703	
2214	JMP 703	If 70 or greater treat as G01.
2215	JMP 2253	

APPENDIX G

CIM-X-A6
(Changes to Bostomatic Absolute Program)

LOCATION	INSTRUCTION	COMMENT
15435	JMP 15600	
15600	LDA 304	
15601	STA 15570	To make I, J, K, modal.
15602	LDA 305	
15603	STA 15571	
15604	LDA 15306	
15605	STA 15572	
15606	LDA 307	
15607	STA 15573	
15610	JMP* 774	
2331	15611	
2070	JMP* 2331	
15611	STA 15670	
15612	LDA 15570	
15613	STA 304	
15614	LDA 15571	
15615	STA 305	
15616	LDA 15572	
15617	STA 306	
15620	LDA 15573	
15621	STA 307	

APPENDIX G (cont'd)

LOCATION	INSTRUCTION	COMMENT
15622	LDA 15670	
15623	JMP* 15624	
15624	2430	
2235	STA 2301	
2236	LDA 2300	If G93 replace B by X.
2237	CAS 101 (1)	
2240	JMP 2242	
2241	JMP 2244	
2242	LDA 2301	
2243	JMP 2064	
2244	LDA 2301	
2245	CAS 242 (B)	
2246	JMP 2064	
2247	JMP 2251	
2250	JMP 2064	
2251	LDA 167 (X)	
2252	JMP 2064	
2213	JMP* 505	
2222	JMP* 505	
2061	JMP* 2315	
2315	12635	

APPENDIX G (cont'd)

LOCATION	INSTRUCTION	COMMENT
12635	CAS 167	
12636	JMP* 12700	
12637	JMP 12641	Check if it is a X.
12640	JMP* 12700	
12641	STA 12701	
12642	LDA 12702	
12643	CAS 101	
12644	JMP 12646	Check if G01 after a G93.
12645	JMP 12650	
12646	LDA 12701	
12647	JMP* 12700	
12650	LDA 160	Change SF to 1 when G01 after G93 and X occurs.
12651	STA* 12703	
12652	CRA	
12653	STA* 12704	
12654	LDA 12701	
12655	JMP* 12700	
12700	2235	
12701	Temp. storage for A	
12702	G01 after G93 flag	
12703	10125	
12704	10126	

LOCATION	INSTRUCTION	COMMENT
2313	15625	
2777	223	
2776	160	
2212	CAS 223 (7777)	Compare G code.
2213	JMP* 505	
2214	JMP* 2313	
2215	JMP* 2326	
2216	LDA 133	
2217	STA 2300	
2220	LDA 2301	
2221	CAS 223 (93)	
2222	JMP* 505	
2223	JMP 2230	
2224	CAS 160 (2276) (70)	
2225	JMP 703	
2226	JMP 703	
2227	JMP 2253	
2253	CAS =4	
2254	JMP* 505	
2255	JMP* 505	

APPENDIX G (cont'd)

LOCATION	INSTRUCTION	COMMENT
2230	STA 2301	
2231	LDA 101 (1)	
2232	STA 2300	If G93, store 1 in 2300.
2233	LDA 2301	
2234	JMP 703	
2326	12710	
12706	2301	
12707	15656	
12710	STA* 12706	
12711	LDA 12702	
12712	CAS 101	Check if G01 after a G93.
12713	JMP* 12707	
12714	JMP* 12730	
12715	JMP* 12707	
12730	2216	
12731	15627	
12732	2300	
15626	JMP* 15666	
15666	12716	

LOCATION	INSTRUCTION	COMMENT
12716	CRA	
12717	STA 12702	
12720	JMP* 12731	
12740	LDA* 12732	
12741	CAS 101	
12742	JMP* 12730	Check if it a G93.
12743	JMP 12745	
12744	JMP* 12730	
12745	STA 12702	
12735	2124	
12746	CRA	
12747	STA* 12703	
12750	LDA 12735	If G93, change scale factor.
12751	STA* 12704	
12752	JMP* 12730	
15656	LDA 160	
15657	STA* 15650	Set scale to 1.
15660	CRA 140040	
15661	STA* 15651	
15662	JMP* 15477	
15477	12740	

APPENDIX G (cont'd)

LOCATION	INSTRUCTION	COMMENT
15625	STA 15646	
15626	JMP* 15666	
15627	STA* 15650	
15630	LDA 15655	
15631	STA* 15651	
15632	LDA 15646	
15633	JMP* 15654	
15650	10125	
15651	10126	
15654	2230	
15652	000000	
15653	2124	

APPENDIX H

CINCINNATI TURNING CENTER

LOCATION	INSTRUCTION	COMMENT
502	DAC '17000,1	
773	DAC '14475	
775	DAC '5532	
776	DAC '5534	
777	DAC '14463	
5524	JMP* '777	JUMP on negative value check if character
14463	LDA INBF+169,1	before minus is an I.
14464	CAS '271	
14465	JMP *3	May be J, K.
14466	JMP *3	Yes
14467	JMP* '773	No
14470	CAS '222	Check if it is a K.
14471	JMP* '773	Not I, J, K.
14472	JMP *1	Yes
14473	LDA '260	It is a I, J, K, replace by a +.
14474	JMP* '776	
14475	LDA '200	Leave it as a -.
14476	JMP* '775	

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